BEFORE THE ARIZONA CORPORATION COMMISSION

COMMISSIONERS
LEA MARQUEZ PETERSON, Chair
SANDRA D. KENNEDY
JUSTIN OLSON
ANNA TOVAR
JIM O'CONNOR

IN THE MATTER OF RESOURCE PLANNING AND PROCUREMENT IN 2019, 2020 AND 2021	Docket No. E-00000V-19-0034

Independent Analysis of Arizona Public Service's 2020 Integrated Resource Plan

The Southwest Energy Efficiency Project (SWEEP) is pleased to provide the attached report that provides an independent analysis of the energy system and ratepayer impacts of Arizona Public Service Company's (APS) 2020 Integrated Resource Plan.

The analysis was conducted by Strategen Consulting, a leading energy modeling and research firm with extensive national experience working with Fortune 500 corporations, state governments, and utilities.

Using data from APS, Strategen built a model of the utility's power system and determined the state's cheapest, most reliable mix of energy options moving forward over the next 15 years.

The key findings of the analysis include the following:

- Strategen identified the optimal, least-cost electricity generation resource portfolio that can reliably meet APS customers' needs from 2021 through 2035.
- This "Optimal Portfolio" is characterized by:
    - Robust continued investment in energy efficiency, with cumulative savings equivalent to ~15% of retail sales over the next decade,
    - The economic retirement of the Four Corners Power Plant in 2023 (the assumed earliest practicable date),
    - A significant expansion of renewable energy and battery storage totaling over 5,200 MW and 3,200 MW (respectively) in new resource additions,
    - Maintenance of zero-carbon electricity from the Palo Verde Nuclear Generating Station,
    - The integration of high-quality wind resources from New Mexico, and
    - A modest decline in natural gas generation from existing resources.
- There is no need for new investment in fossil resources, which could quickly become stranded assets as the utility has committed to 100% clean, carbon-free electricity by 2050.
- When compared to a "Reference Portfolio" that approximates "business as usual," the Optimal Portfolio reduces total electricity system generation costs by $1.4 billion (net present value) through 2035, thereby yielding significant corresponding benefits to APS customers.

- The Optimal Portfolio produced cumulative carbon emissions over the 15-year period that were 50% lower than the Reference Portfolio.

Based on the modeling results, SWEEP recommends that the Commission immediately act to finalize and implement its Energy Rules. The Energy Rules are directionally consistent with the Optimal Portfolio and would institute consumer protections and future-proof our grid so that APS prioritizes resources that would save billions of dollars for its customers.

Additionally, the Commission should:

- Direct APS to:
    - Eliminate coal unit “must-run” designations for future resource planning and modeling,
    - Remove modeling restrictions that limit the amount of energy efficiency that can be selected as a resource option,
    - Remove modeling restrictions that prevent the economic cycling and economic retirement of coal units,
    - Update its assumptions for hydrogen to include a full accounting of the sources and costs of the hydrogen fuel and any associated capital expenditures to produce that fuel,
    - Update its five-year Action Plan to achieve an annual minimum of 1.5% energy savings as a percent of retail sales from a broad portfolio of energy efficiency measures (consistent with 15% cumulative savings over ten years)
    - File quarterly reports on the accuracy of its load forecast, including weather-normalized values for energy and peak load
    - Refresh its IRP assumptions and results based all of the above as well as key new developments, including the extension of key tax credits (i.e. the Investment Tax Credit and the Production Tax Credit) and its plan to run one of the Four Corners units seasonally
    - Include, as part of future IRPs, information on how each portfolio performs in terms of total cumulative emissions reductions in addition to annual emissions numbers.

- Evaluate the costs and benefits of the economic retirement of the Four Corners Power Plant before 2031 by assessing the prudency of continued operations of the Plant past 2023 and/or another date or dates selected by the Commission.

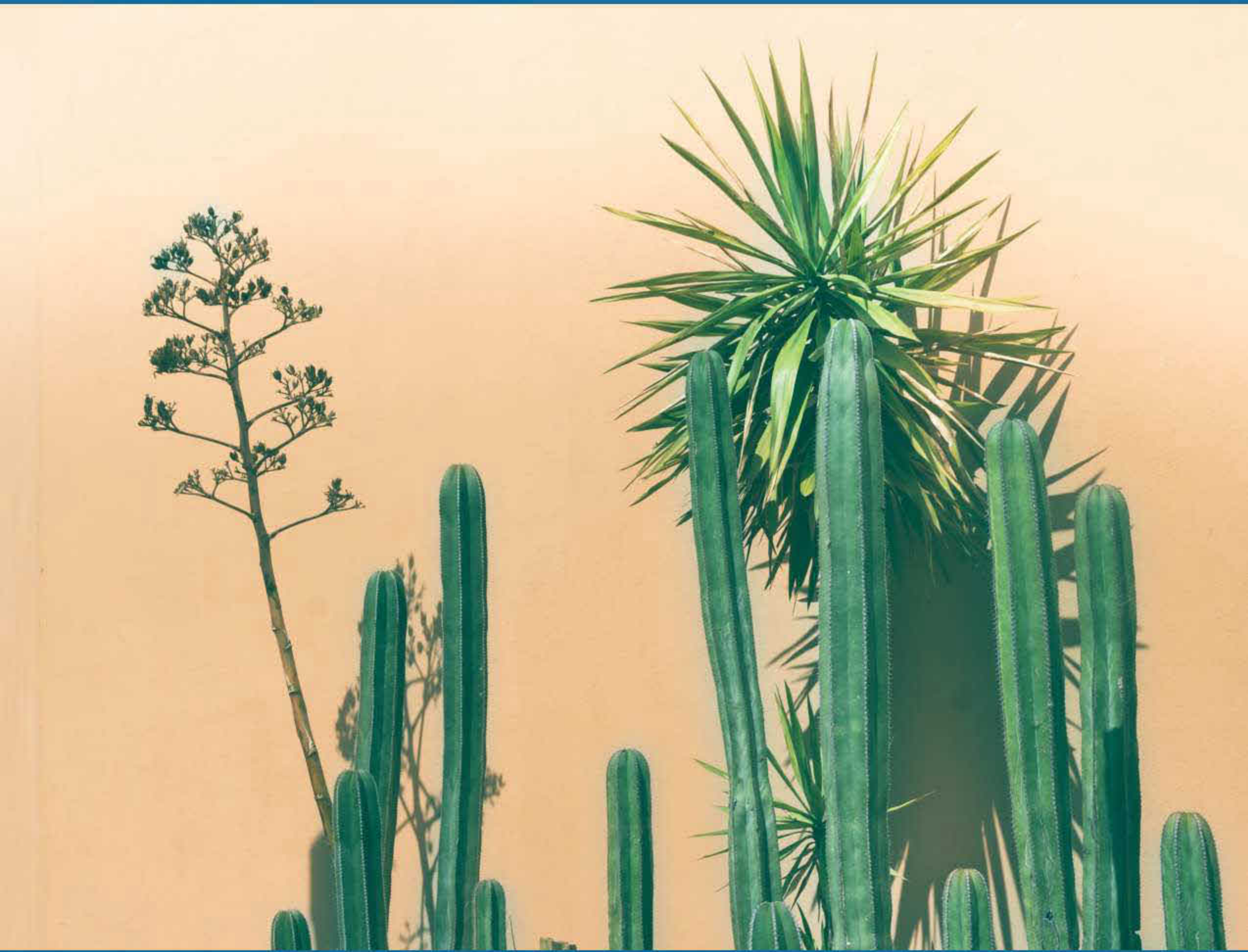
- Take expeditious action to finalize and approve a recommendation on Just and Equitable Transition (JET), including by setting aside a portion of the $1.4 billion in cost savings to assist impacted communities in the transition to new economic bases.

Sincerely,

Ellen Zuckerman
Director, Utility Program, SWEEP

Caryn Potter,
Manager, Utility Program, SWEEP

ANALYSIS OF ARIZONA PUBLIC SERVICE'S INTEGRATED RESOURCE PLAN



STRATEGEN

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APRIL 28, 2021

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Disclaimers

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Contents

Executive Summary

Arizona Public Service Company (APS) submitted its 2020 Integrated Resource Plan (IRP) to the Arizona Corporation Commission (ACC) on June 26, 2020.[1] The Southwest Energy Efficiency Project (SWEEP) partnered with Strategen Consulting LLC to conduct grid modeling and technical analysis to identify portfolios that meet the utility's stated clean energy commitments and maintain affordable and reliable service for customers, and explore whether additional environmental and economic savings could be achieved.

Although affordability, grid reliability, and environmental benefits are frequently presented as competing interests, this analysis reveals that they can co-exist without significant trade-offs and can be simultaneously maximized with strategic investment and operational choices. Energy efficiency (EE), renewable energy (RE) resources, and energy storage technologies are becoming more affordable, while also providing flexibility and significant environmental benefits without impacting reliability.

Our analysis demonstrates that energy efficiency is one of the most economic resources to be added to the system and recommends that APS increase its investment in it. Furthermore, we find that the remaining coal units in APS's system are highly uneconomic, and an earlier retirement date for all remaining coal units would result in both cost savings and emissions reductions for Arizonans.

The key findings of Strategen's analysis in this study can be summarized as follows:

- Strategen identified the optimal, least-cost electricity generation resource portfolio that can reliably meet APS customers' needs from 2021 through 2035.
- This "Optimal Portfolio" is characterized by:
    - Robust continued investment in energy efficiency, with cumulative savings equivalent to ~15% of retail sales over the next decade,
    - The economic retirement of the Four Corners Power Plant in 2023 (the assumed earliest practicable date),
    - A significant expansion of renewable energy and battery storage totaling over 5,200 MW and 3,200 MW (respectively) in new resource additions,
    - Maintenance of zero carbon electricity from the Palo Verde Nuclear Generating Station,
    - The integration of high-quality wind resources from New Mexico, and
    - A modest decline in natural gas generation from existing resources.
- There is no need for new investment in fossil resources, which could quickly become stranded assets as the utility has committed to 100% clean, carbon free electricity by 2050.[2]
- When compared to a "Reference Portfolio" that approximates "business as usual," the Optimal Portfolio reduces total electricity system generation costs by $1.4 billion (net present value) through 2035, thereby yielding significant corresponding benefits to APS customers.
- The Optimal Portfolio produced cumulative carbon emissions over the 15-year period that were 50% lower than the Reference Portfolio.

[1] https://docket.images.azcc.gov/E000007312.pdf

[2] https://www.aps.com/-/media/APS/APSCOM-PDFs/About/Our-Company/Energy-Resources/CleanEnergyReport.ashx?la=en#:~:text=We%20are%20making%20a%20commitment,portfolio%20coming%20from%20renewable%20energy.

We find that the recently announced seasonal operations of one of the units of the Four Corners Power Plant can reduce carbon emissions and can potentially deliver significant cost savings. However, given APS's contractual obligations while the plant is operating, these savings are much more limited, and we recommend that the utility pursue additional savings by retiring the Four Corners units early.

Strategen's recommended Optimal Portfolio including higher levels of energy efficiency, the retirement of Four Corners by the end of 2023, continued investment in clean energy, and no new investment in fossil fuel resources results in savings of over $1.4 billion for APS ratepayers.

1. Introduction

This report provides an assessment of several potential energy resource portfolios, each of which could reliably serve the needs of APS customers, though each have different costs and clean energy outcomes. Strategen developed and analyzed these portfolios on behalf of SWEEP, using the EnCompass modeling platform. As part of this assessment, Strategen identified several key portfolio elements that we believe can assist APS in simultaneously achieving both a more affordable and cleaner energy portfolio for its customers than what the company initially presented in its 2020 IRP.

Several recent developments have already caused APS's original 2020 plan to be out of date, including:

- APS's recent announcement to begin seasonal operations at one of the Four Corners units.[3]
- The extension of the federal tax credits for solar and solar plus storage.[4]

Additionally, APS's plan did not consider the economically optimal level of energy efficiency or the economically optimal retirement date of the Four Corners Power Plant. Moreover, after reviewing APS' 2020 IRP, Strategen identified several input assumptions that we believe needed to be updated or corrected. As an example, APS's plan did not fully consider certain costs associated with green hydrogen fuel production necessary to power future combustion turbines with a carbon-free energy source.

Strategen considered all of these factors in developing an alternative resource portfolio for APS that can reliably meet APS customers' needs from 2021 through 2035 at least cost. Our primary recommendations include higher investments in energy efficiency, as well as the economic retirement of the Four Corners units prior to 2031. These strategies not only reduce greenhouse gas emissions, but also save billions in operational costs while maintaining reliability, mitigating risks, and allowing for a smooth transition to a cleaner portfolio.

Our analytical approach and resulting recommendations were informed by the following research questions:

1. What is the least cost/"optimal" mix of resources for APS's system?
2. When should coal units be retired based on economic considerations (if given the option to economically retire)?
3. What are the environmental impacts from the economic retirement of coal?
4. How should coal units be dispatched if operated based on economic cycling?
5. How much energy efficiency is economically optimal when modeled as a resource option versus a fixed load modifying assumption?
6. How does the selection of energy efficiency measures impact APS's energy and capacity needs?

[3] https://www.aps.com/en/About/Our-Company/Newsroom/Articles/aps-announces-plans-for-seasonal-operations-at-four-corners-power-plant

[4] https://www.greentechmedia.com/articles/read/solar-and-wind-tax-credit-extensions-energy-rd-package-in-spending-bill-before-congress

7. How does the selection of energy efficiency measures vary based on cost, hourly shape, coincident peak, and savings? And how can this selection be optimized to best meet the evolving needs of the regional power grid (e.g., the growing availability of daytime solar)?

2. Approach

2.1. Modeling Methodology

In conducting this analysis, Strategen used the EnCompass power planning software tool, developed by Anchor Power Solutions.[5] EnCompass is commercially available and is widely used by utilities, consultants, and practitioners in the power industry. It is accompanied by a dataset called the Horizons Energy database that provides information on the U.S. electricity grid. EnCompass uses advanced programming techniques to determine the optimal investment and operational decisions for a specified set of generators on the power grid. For example, it can be configured to examine an individual utility, or a broader grid region. The optimization routine seeks a specific objective function subject to a set of constraints. In this modeling exercise, the objective function was to minimize costs while ensuring that constraints such as the reserve planning margin and energy needs are met in each hour of the year. EnCompass can be configured either as a capacity expansion model or a production cost model.

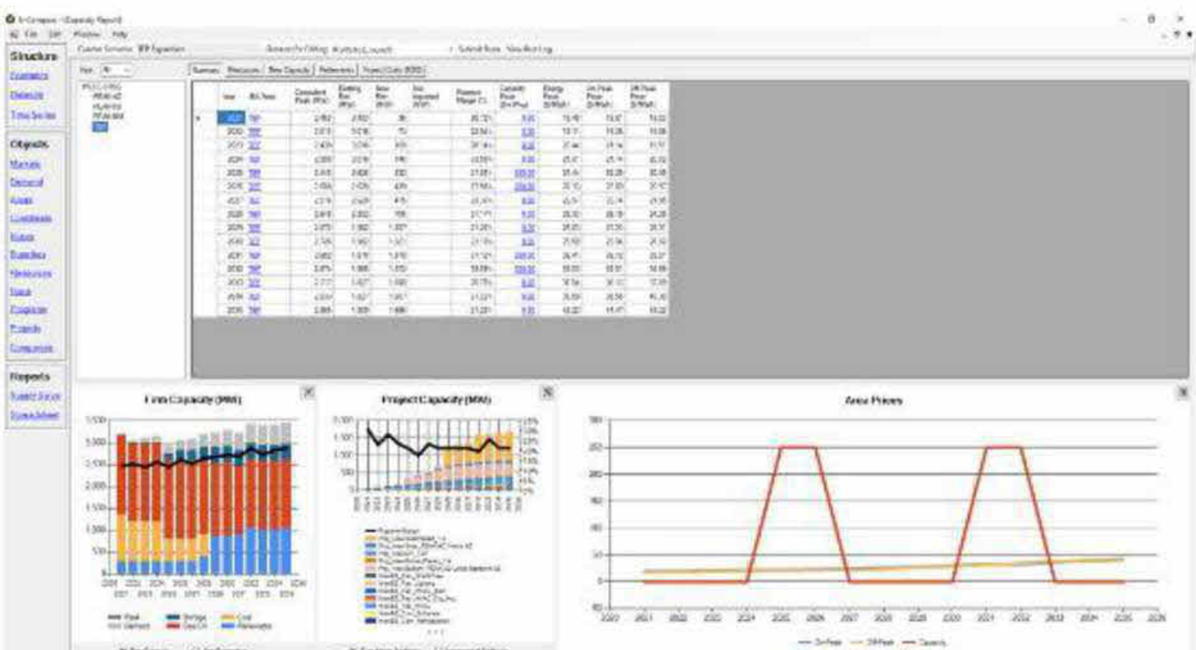

Figure 1: Snapshot of the EnCompass User Interface

A capacity expansion model finds the least cost resource portfolio that reliably meets the projected electricity demand over a period of several years. A production cost model, on the other

5 https://anchor-power.com/encompass-power-planning-software/

hand, finds the least cost dispatch of a given or pre-determined system of generators. Capacity expansion models have been traditionally used to provide investment guidance, while production cost models have been employed to provide answers to short-term operational questions or to perform comparisons of pre-selected or pre-determined portfolios.

For this study, EnCompass was run as a capacity expansion model with a planning horizon of 2035, consistent with APS' 2020 IRP. In this mode the model determines not only the most economic way to utilize existing resources, but also the type and quantity of new resources that should be added in the future, and whether existing resources should be retired and when. In each simulation, individual resource decisions are made to ensure that the overall portfolio will meet the forecasted energy and peak demand, while also meeting any policy goals outlined.

The figure below provides an illustration of the inputs and outputs of a capacity expansion model.

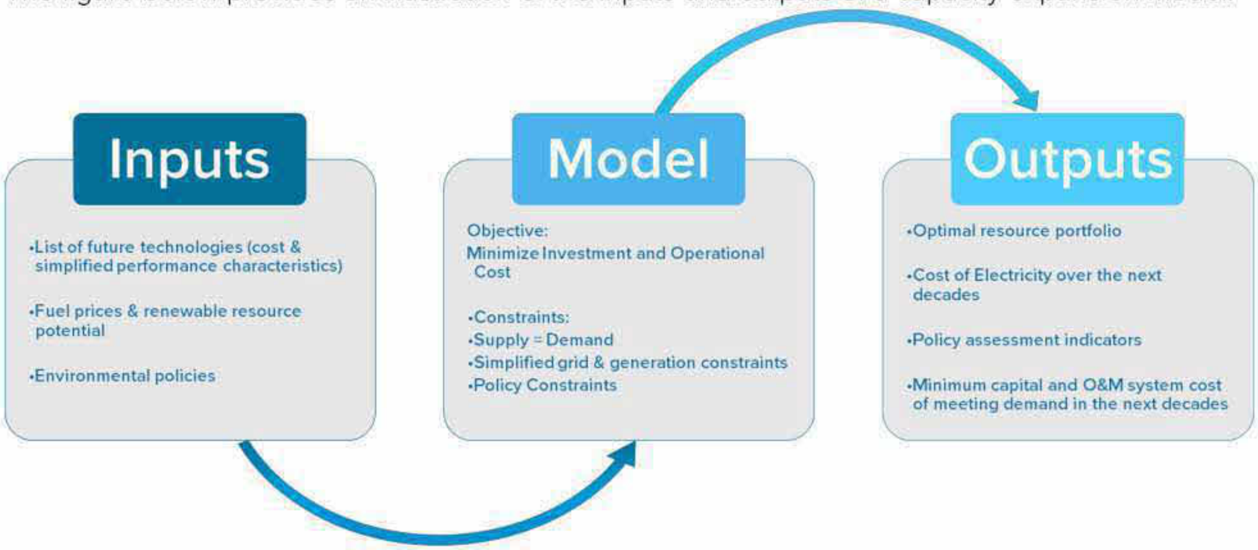

Figure 2: Capacity Expansion Model: inputs & Outputs

2.2. Model Inputs and Assumptions

Horizons Energy provides a dataset that accompanies the EnCompass model and includes all of the generation units, resource characteristics, and grid details of the U.S. power system. The analysis conducted for this study used the Arizona data from the Horizons Energy database as a starting point. It was then updated to include APS's specific 2020 IRP assumptions, as well as adjustments based on recent policy developments and the Strategen team's expert judgement.

2.2.1. Load Forecast

Forecasting load is a foundational component of a resource plan and is fundamental for analyzing the number, timing, and types of resources a utility needs. The forecast is long-term in nature, with more emphasis placed on the near-term, as the near-term outlook guides short-term decision-making in a utility's three-to-five year "Action Plan" window, while the long-term forecast is important for developing a long-term strategy and directional resource targets and assessing policy impacts.

The present analysis uses the load forecast from APS's 2020 IRP filed with the ACC. APS' 2020 IRP considers a peak consumption hour growth rate under three scenarios: (1) a "Base Assumption" scenario with a 2.1% annual growth rate; (2) a scenario with a forecast growth rate of 0.9%, and (3) a scenario with no growth or 0%. Annual growth rates reflect peak load growth after customer resources (including energy efficiency and distributed energy are accounted for). For the purposes of this analysis, Strategen used the 0.9% growth scenario, which more closely matches recent trends.[6]

APS forecasts its retail sales and wholesale obligations and then subtracts the separately forecasted demand side resources (including both energy efficiency and distributed generation). However, for the purposes of this analysis, Strategen modeled energy efficiency endogenously in the capacity expansion model, to provide a more accurate cost comparison of supply and demand side resources. Thus, for this modeling exercise, Strategen used the same gross load forecast included in APS' IRP (i.e., prior to the effects of distributed generation and energy efficiency). Distributed generation was then subtracted equal to APS' IRP assumptions. This method using the gross load (net of distributed generation) allows for energy efficiency to be selected by the model as a resource in the optimal mix, rather than being predetermined and embedded in the load forecast.

2.2.2. Resource Characteristics

Cost and performance characteristics including heat rates, minimum levels of operation, variable operations and maintenance (O&M) costs, fixed O&M, and incremental capital expenses were updated in the Horizons database based on APS's 2020 IRP.

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[6] For example, APS' year-over-year growth in retail sales (weather normalized) in 2017, 2018, and 2019 was (0.3)%, 0.1%, and 0.6% (respectively). This is based on information reported in Pinnacle West Annual Statistical Reports: http://www.pinnaclewest.com/investors/reports/annual-statistical-report/default.aspx

2.2.3. Price Forecasts

The analysis uses the annual fuel prices, hourly wholesale market prices for the Palo Verde node, and carbon price included in APS's 2020 IRP.

2.3. Other Model Input Adjustments

2.3.1. Federal Tax Credits for Renewable Energy

In December 2020, the U.S. Congress passed a spending bill that includes $35 billion in energy research and development programs, a two-year extension of the Investment Tax Credit (ITC) for solar power, a one-year extension of the Production Tax Credit (PTC) for wind power projects, and an extension through 2025 for offshore wind tax credits. The two-year extension of the federal ITC for solar projects will retain the current 26% credit for projects that begin construction through the end of 2022, rather than expiring at the end of 2020 as they would have under prior law. The ITC will fall to a 22% rate for projects that begin construction by the end of 2023, and then fall to 10% for large-scale solar projects and to 0% for small- scale solar projects in 2024. Additionally, many of the large-scale solar developments set to be completed through 2023 have used "safe-harbor" provisions to secure the original 30% ITC credit (as long as they are completed within four years), thereby removing the risk of a disruption in project financing as a result of a tax credit reduction.[7] Similarly, many wind projects have used safe harbor provisions to secure the PTC at a higher level. Through "commence-construction" or "safe-harboring" provisions by 2023, solar ITC projects can secure the 26% and 22% credits in 2022 through 2025. Below is a table of the ITC that was modeled for solar photovoltaic (PV) and solar PV plus storage projects by commercial date of operation:

Commercial Date of Operation	ITC (%)
1/1/2021-12/31/2022	30%
1/1/2023-12/31/2023	26%
1/1/2024-12/31/2024	22%
After 1/1/2025	10%

Table 1. Safe Harbor Assumptions for Federal ITC

Similarly, the one-year extension for the PTC combined with the safe harbor provisions were modeled as shown below:

Commercial Date of Operation	PTC (%)
1/1/2021-12/31/2021	80%
1/1/2022-12/31/2023	60%
After 1/1/2024	0

Table 2. Safe Harbor Assumptions for Federal PTC

[7] Safe harbor refers to IRS guidelines such that project developers can secure the federal ITC when construction begins (including purchase of equipment), as long s the project is placed into service within 4 years.

2.3.2. *Capital Costs for Renewable & Storage Technologies*

The capital cost of paired solar plus storage resources was adjusted down to reflect the fact that DC-coupled solar plus storage systems share common power conversion equipment and interconnection costs that would not need to be duplicated. Furthermore, future wind capital costs were adjusted to be more consistent with other forecasts from the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) and other industry sources.

2.4. Availability & Operations of Resources

2.4.1. *Coal Operations & Retirement*

APS's supply resources include a significant percentage of coal-fired generation: APS's share of the Four Corners Power Plant accounts for approximately 970 MW.

Coal Unit Operations

Traditionally, coal units have been considered a baseload resource and were designed to turn on and stay on, running all year round and meeting the portion of demand that appears constant in aggregate. Baseload resources have historically had high capital costs but low operating costs, and as such it was economic to run them most of the time, resulting in high capacity factors.

However, coal units are not well-suited to serve as baseload resources anymore. On the contrary, they are now some of the most expensive resources in an electric system due to the declining cost of alternative technologies including solar, wind, natural gas, and batteries. New patterns of net demand also mean they are not needed in every hour of the year. Unfortunately, in many regions, despite the clear change in system economics, the past practices of running coal units as baseload resources have not changed, resulting in uneconomic operations and higher costs to utility customers. While in real world operations, utilities can choose to operate their units regardless of economic considerations, within a mathematical model that is designed to optimize for the least cost resources (such as EnCompass), the continued operation of coal units can only be achieved by the introduction of artificial constraints dictating that those units should remain online despite their higher cost. These constraints are often called "Must-Run" constraints and reflect a scenario where a plant operates even if it is uneconomic to do so. These constraints can be added into resource planning models based on historic or current policy decisions. The relaxation or elimination of such constraints both in the modeling, as well as in real life operations, is often called "economic cycling" or "economic dispatch"[8] and reflects a scenario where a plant operates only when it is economic to do so.

Acknowledging that some utilities follow this common practice of including Must-Run constraints in their modeling, we initially ran EnCompass in a similar manner, requiring the continued operation of coal units; and then later eliminated those constraints. It is worth noting that APS designates both

[8] Sometimes this is also referred to as "security constrained economic dispatch"

Four Corners Unit 4 and Unit 5 as Must-Run in its AURORA modeling. The AURORA platform is used by APS as a production cost model, i.e., it optimizes unit operations based on a pre-specified fleet of generators, which in this case includes the Four Corners units. Even without investigating an earlier retirement option (which would eliminate significant future O&M and incremental capital expenses at the plant), APS chose to incorporate Must-Run constraints in the modeling to ensure the units would run even if uneconomic.

Relaxing Must-Run constraints to allow for economic cycling throughout the year can lead to significant operating cost savings for electricity customers and emissions reductions. These savings are available immediately since the fuel and O&M costs for coal-fired electricity are already significantly more expensive than other available resources (even when accounting for construction costs of new resources like wind and solar). Meanwhile certain conditions, like minimum tonnages in existing coal supply agreements might limit the fuel cost savings potential for some units. However, before dismissing the idea of economic cycling or economic retirement, the utility should first investigate any provisions that could allow for an early termination of the contract and any associated penalties. Those penalties should be compared against the forecasted O&M, capital, and fuel savings of economic operations and retirement and only then an optimal decision can be made. A more detailed discussion on the existing Coal Supply Agreement for Four Corners is included in the next section.

After the IRP filing in June 2020, APS announced an agreement among the Four Corners Power Plant owners: the Navajo Transitional Energy Company (NTEC), the Public Service Company of New Mexico (PNM), Salt River Project (SRP), and Tucson Electric Power (TEP) to move toward operating one unit at the plant seasonally beginning in the fall of 2023, subject to necessary approvals.[9] The agreement comes as PNM announced plans to transfer its plant ownership share to NTEC in 2024. According to the announcement, compared to current conditions, the shift to seasonal operations will reduce annual carbon emissions by an estimated 20-25%, furthering the plant's owners' sustainability commitments.

Coal Unit Retirement

In addition to cycling, the EnCompass model also allows for economic retirement of the coal units. Again, historically, both in real world operations, as well as in modeling, units are often only retired once they reached their economic book lifetime. However, the dramatic reductions in the costs of other resources (e.g., renewables and gas) have challenged this practice. Coal units are becoming increasingly more expensive to operate and maintain in a system, leading to increased consideration of accelerated or economic retirement throughout the industry. This concept has started spreading worldwide as new capital investment in renewable resources, often paired with energy storage, can be much more cost competitive when compared to the operating expenses of keeping a coal unit in the system. This has led to decisions to retire fossil fuel plants based on economics even before their economic book life is reached.

[9] APS announces plans for seasonal operations at Four Corners Power Plant, 3/12/2021

Allowing economic retirement means that the model can not only select which units to invest in, but it can also retire a unit before its scheduled retirement date, if doing so would achieve overall cost savings for electricity customers. This decision is based on a forward-looking analysis, i.e., retirement decisions account for the avoidable costs should a unit retire early and is not limited by the unavoidable costs associated with a unit's undepreciated balance of plant. Based on economic theory, undepreciated capital expenses are considered "sunk costs" and should not be the deciding factor for future investments. Indeed, these costs will likely be borne by utility customers, regardless of when the plant retires.

If undepreciated balance of plant costs exist, then it becomes a policy matter for the Arizona Corporation Commission to decide whether, how, and when these "stranded costs" should be recovered if a plant is retired early. However, it is important to recognize that customers can benefit from economic retirements regardless of whether they pay these fixed costs (i.e., "stranded costs") following plant retirement. Keeping uneconomic units online solely to allow for full book life to be realized only results in higher costs for utility customers due to the ongoing operating costs and new capital costs incurred.

In APS's specific case, it is worth noting that the company made significant recent investments in Selective Catalytic Reduction (SCR) equipment at both Unit 4 and Unit 5 at Four Corners Power Plant. Cost recovery of these investments through retail rates has not yet been authorized by the Arizona Corporation Commission. The lack of certainty APS faces regarding cost recovery of these major investments is likely the largest single barrier to the Company opting for an earlier retirement date, and thereby achieving additional operating cost savings for its customers. If the ACC were to deny rate recovery of the SCR costs, then there would be much less capital investment at stake over which APS may be inclined to keep the plant open (and thus an earlier retirement date might be seen as more feasible from the Company's perspective). In contrast, if the ACC were to grant rate recovery of the SCRs, APS may be inclined to keep the plant operational until the SCR costs were fully recovered (e.g., in the 2030s). Alternatively, the Commission could opt to grant full or partial recovery of the SCR costs as a regulatory asset even after the plant is retired, thereby making APS whole on its investments, while still achieving the additional costs savings identified in this analysis.

2.4.2. Energy Efficiency

As part of the integrated resource planning process, each Arizona utility has projected energy savings from implementing energy efficiency measures over the next 15 years. This forecast is not usually part of the capacity expansion model and is instead based on separate studies conducted prior to the selection of the rest of the supply resources. However, this different treatment of demand side and supply side resources can lead to significant economic inefficiencies and increased ratepayer cost if the full economic potential of efficiency measures is not considered. Energy efficiency that may be economic when compared with alternative supply resources can be left untapped if not considered in the scope of a capacity expansion model.

The analysis conducted in this study treats energy efficiency measures on a level playing field to supply resources. This is done by including energy efficiency measures as resources that can be selected, with a first-year cost and subsequent energy savings based on actual measures and their end use load shapes. The utility provided information on the set of measures that are available within their systems together with their cost, lifetime, hourly load shape, and annual market potentials through a non-disclosure agreement. Strategen modeled each of these measures independently and included them as a resource option in the capacity expansion modeling exercise. From the first explorative runs, it became apparent that the majority of those measures are economic compared to their supply side counterparts and the efficiency level of the Optimal Portfolio primarily depends on each measure's assumed market potential, i.e., what energy efficiency level is available for the model to include in the portfolio. For modeling purposes, we allowed the full economic potential energy efficiency measures to be selected.[10]

The measures modeled are representative of the broader set of measures in APS's energy efficiency program portfolio and include both residential and commercial sector programs, and end uses such as lighting, HVAC, hot water heating, industrial motors, refrigeration, and so on. The graphs below show the variety of measures[11] that are available for APS.

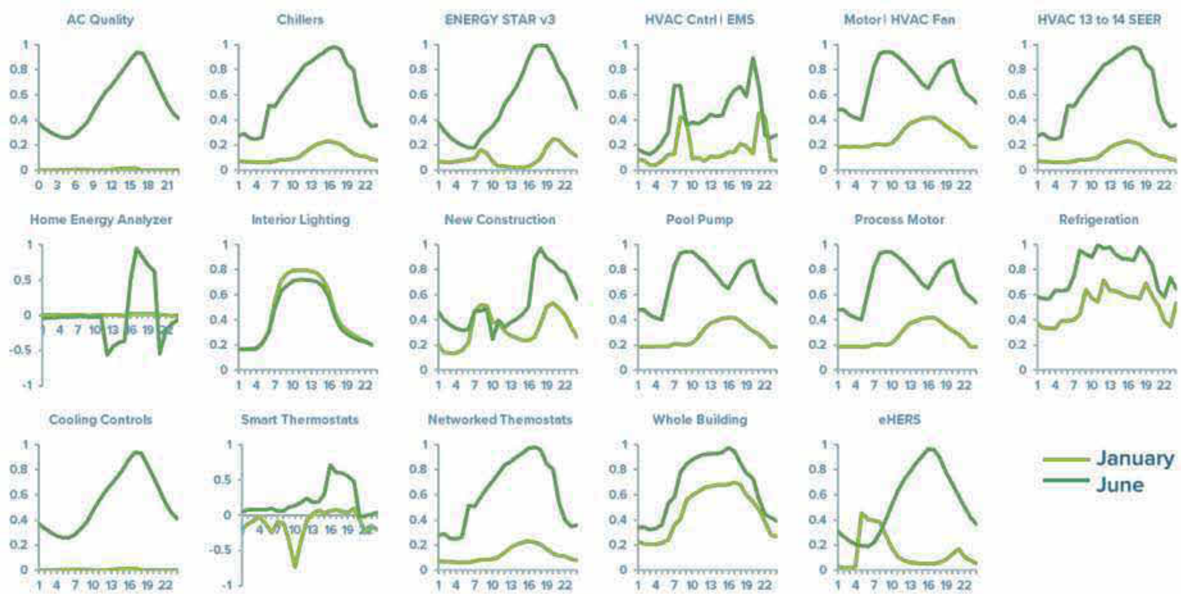

Figure 3: Hourly profile of APS EE measures (average over year)

Based on our analysis, we believe that APS' 2020 IRP may be underestimating the potential savings per year that could be achieved through energy efficiency. In the first ten years of their efficiency program implementation, APS has succeeded in achieving energy efficiency savings, at

[10] Economic potentials are determined by the utilities based on the evaluation method historically used by the ACC. Strategen believes this method to be a conservative approach that may not fully represent the full economic potential available. Additionally, the Energy Rules redefine energy efficiency cost effectiveness to mean "prudency." Thus the ACC's historic method of determining cost effectiveness would no longer be the practice going forward should the Energy Rules be finalized and implemented.

[11] The measures included in this analysis were AC Quality, Chillers, Energy Star Version 3, Heating, Ventilation, and AC Control (HVAC Cntrl I EMS), HVAC 13 – 14 SEER, Home Energy Analyzer, Interior Lighting, New Construction, Pool Pump, Process Motor, Refrigeration, Cooling Controls, Smart Thermostats, Networked Thermostats, Whole Building, and the electronic Home Energy Rating System (eHERS).

costs that were lower than originally predicted.[12] Given this past performance, and the technological and cost advancements in energy efficiency, the level of increase in efficiency planned by the utilities appears conservative and thus limits the potential for energy efficiency to reduce costs and emissions for Arizona's ratepayers.

2.4.3. Wind

Consistent with Arizona utilities' planning practices, new transmission lines were not endogenously modeled. However, as coal plants retire, particularly those in Eastern Arizona and New Mexico (e.g., Four Corners, Springerville, and San Juan), some transmission capability could potentially be repurposed to support wind imports. However, this may still be insufficient and new lines may be needed. To reflect this consideration, we included an upper limit on the amount of out of state wind that could be selected by the model equal to 800 MW. Additionally, lower quality, in-state wind resources were allowed to be selected.

2.4.4. Hydrogen Ready Combustion Turbines

In its Bridge Portfolio, APS includes new gas turbines that are described as "hydrogen ready." It is important to note that while there are theoretically many ways to produce hydrogen fuel, including from renewable energy, most of it today is generated from fossil sources. There are significant efforts under way to increase "green hydrogen" production. If APS ultimately includes combustion turbines in its portfolio, it will be necessary for it to also identify a reliable source of green hydrogen to power these turbines. Without a source of green hydrogen, the turbines will need to use hydrogen generated from fossil fuels, or simply fossil gas. In this case, APS risks having these turbines become stranded assets, since they will be incompatible with APS's commitment to achieve 100% carbon-free energy by 2050.

Strategen believes additional clean, dispatchable resources like green hydrogen will eventually become important to consider and include, particularly as the clean energy mix approaches the 80% level. Hydrogen turbines using green hydrogen fuel might be one of the technologies satisfying those criteria in the future. However, it is worth noting that turbines capable of burning 100% hydrogen without exceeding NOx emissions limitations are not commercially available today. Existing technology (including both turbines and pipelines) can accept a limited blend of hydrogen fuel, however this is limited to about 20-30% before technical limits are reached. While vendors are actively developing 100% hydrogen capable technologies that do not exceed NOx limits, we estimate that these will not be commercially available for about 5-7 years. Thus, the cost and technological readiness of 100% hydrogen turbines is somewhat uncertain at the moment.

The addition of new solar, and wind, in combination with maintaining the existing nuclear generation capacity at Palo Verde, can achieve a large majority of the emissions reductions APS has committed to. However, as the penetration of renewable resources increases – particularly in the 2030 to 2050 timeframe – it becomes more challenging to reach the 100% target at a low cost without some additional resource options that can provide firm, dispatchable clean energy. While these resources

[12] Refer to the 2010-2019 Annual Demand Side Management reports of Arizona Public Service Company filed with the Arizona Corporation Commission

may not be needed in the short term (i.e., before 2030), they should be considered over a longer planning horizon, or under a more aggressive emissions reduction target. Resources that fall into this category could include: 1) much larger installations of battery storage that extend beyond the typical 4-6 hour timeframe, 2) geothermal, for which there are high quality resources available nearby in Nevada and Southern California, and 3) combustion turbines that burn "green hydrogen" fuel produced from a renewable energy source.

Our analysis is agnostic about which, if any, of these "firm clean" resources is more likely to be deployed in Arizona, however we do include a placeholder resource option that represents this. The assumptions for the "firm clean" resource were developed with the third of the above options in mind. As a rough approximation of the cost of a combustion turbine burning green hydrogen, we increased the capital cost of a standard combustion turbine to account for the additional cost of the electrolyzer required to produce hydrogen fuel, as well as the cost of onsite tank storage facility to store the hydrogen fuel. This assumes that hydrogen is produced and consumed on-site, with no need for additional pipeline transportation or underground storage. Furthermore, we also assumed the cost of an incremental renewable resource that would be needed to power the electrolyzer with no emissions. We estimate that these additional costs could place the green hydrogen resource in a similar cost range to a geothermal resource.

While including this new resource, we also limited the model's ability to include conventional combustion turbines using APS' assumed costs, which were based on the conventional technology without any adjustment. We believe the combustion turbine cost assumptions APS included in its 2020 IRP are incomplete since they do not reflect the full cost of green hydrogen production, transportation, and storage as described above.

Below is a comparison of the "hydrogen ready" combustion turbine cost assumptions used by APS, Strategen, and NREL in its recent LA 100 study.[13] When compared to the LA 100 study assumptions, we believe the assumptions used in this study for hydrogen are fairly optimistic. However, as mentioned this could also be representative of another resource type (e.g., geothermal) or significant cost reductions in electrolyzer technology.

Resource (Source)	CapEx	Availability
Large Frame Combustion Turbine (APS)	$652/kW	now
Hydrogen CT (LA100)	$4,542/kW	in 2030
Adjusted CT Assumption(Strategen/SWEEP)	$2,436/kW	In 2028

Table 3: Hydrogen Ready Combustion Turbine Cost Assumptions

[13] https://www.nrel.gov/docs/fy21osti/79445.pdf

3. Resource Portfolios

3.1 Reference Portfolio

In order to evaluate the benefits of an alternative resource portfolio, it is necessary to first characterize a reference portfolio or "business as usual" case. The analysis first evaluated a "Reference Portfolio" which is intended to resemble the modeling decisions for coal operations and energy efficiency that APS used in its 2020 IRP. That is, Four Corners was modeled with a 2031 retirement date and a limited, predetermined EE portfolio was assumed.

Additionally, combustion turbines (CTs) were initially selected under APS's assumptions, however when these assumptions were modified to reflect the "hydrogen-ready" costs described above, the portfolio optimization replaced the CTs with other resources (e.g., battery storage). Had the model been allowed to pick a combustion turbine with the APS's cost assumption, the resulting portfolio would have included natural gas combustion turbines (likely in the late 2020s). However, we find APS's assumed combination of low capital expenses (refer to Table 3) and implied emissions performance to be unrealistic, and thus we do not include this possibility in our analysis as a plausible scenario. Instead, the Reference Portfolio assumes combustion turbine additions with the assumptions outlined in the previous section (i.e., with green hydrogen costs represented).

The Reference Portfolio also included renewable technologies with the input adjustments outlined above, energy efficiency levels as assumed by APS in its load forecast, and Four Corners is operated as Must-Run through its 2031 retirement date.

A variation on the Reference Portfolio was also modeled ("Reference with Seasonal Operations") to better understand the impact of the recent APS announcement to operate one of the Four Corners units seasonally starting in 2023. In this case, the model selects to reduce operations during winter months, indicating that reducing coal operations during the off-peak season is generally economical.

The table below compares the Reference Portfolio against the APS Bridge Portfolio included in APS's 2020 IRP. The main Reference Portfolio of this analysis is intended to be similar to the Bridge Portfolio in most respects, although it differs in some key ways as described throughout this report (for example, we believe the 0.9% load growth sensitivity that APS examined in its IRP, to be more realistic than the higher 2.1% growth scenario that APS assumed, hence leading to a difference in overall resource need).

	APS BRIDGE PORTFOLIO	STRATEGEN REFERENCE PORTFOLIO	STRATEGEN REFERENCE PORTFOLIO (W/ SEASONAL OPERATIONS)
ENERGY EFFICIENCY	1,602	1,602	1,602
DEMAND RESPONSE[14]	693	800	800
DISTRIBUTED ENERGY	1,585	1,585	1,585
RENEWABLE ENERGY	6,450	5,300	5,440
ENERGY STORAGE	4,850	4,770	4,700
MERCHANT PPA (NATURAL GAS)	1,028	1,028	1,028
HYDROGEN READY CTs	831	0	0

Table 4: Capacity Additions (MW) in Reference Portfolio

The graphs below show the generation mix in the fifteen years up to 2035 keeping coal units that are otherwise out of the money online and operating. The graph does not include energy efficiency estimates as those are already included in the APS's load forecast, or energy storage as the resource is not generating electricity.

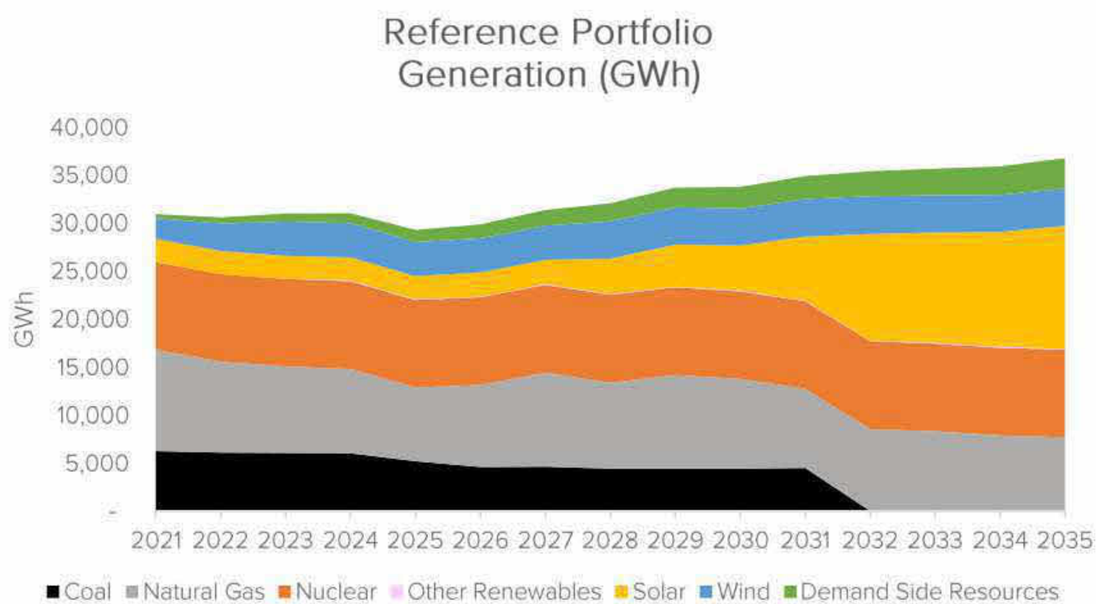

Figure 4: Generation Schedule in Reference Portfolio

[14] Note that the total demand response included in the Reference Portfolio (800 MW) is roughly equivalent to what APS included in its 2020 IRP for the Accelerate portfolio.

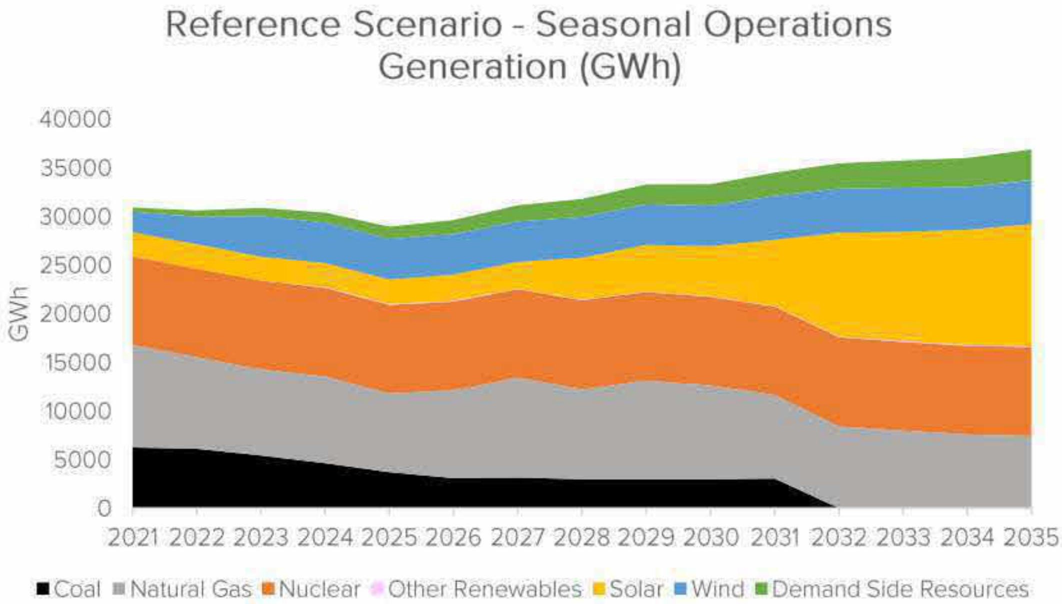

Figure 5: Generation Schedule in Reference Portfolio with Seasonal Operations

When comparing the Reference Portfolio with the Must-Run constraints implemented throughout the year and a scenario that allows for seasonal operations, we find that in the latter scenario, coal generation is replaced by increased renewable energy resulting in both emissions reductions and cost savings. While APS described this change as leading to coal emissions reductions on the order of 20-25%, we find that the entire portfolio's emissions is slightly lower (approximately 15%). Although seasonal operations are definitely able to provide cost savings, it is important to recognize that additional and much larger benefits are still not pursued under this scenario which could arise from accelerated retirement whereby fixed O&M costs and incremental capital expenses are avoided. If the units are not retired, fuel savings are limited by the shortfall payments the utility will have to make due to the reduction of coal consumption according to the fuel supply agreement with NTEC. This means that the truly avoided fuel costs from reducing operations could be relatively small and may not justify investments in other sources that would be needed to replace the coal generation as long as the units are still operational. As an example, the final savings increasing the shortfall payments from the unit that operates seasonally would only amount to $30-$40 million dollars. However, under a full retirement scenario a much greater amount of savings would be realized as explained in the next section.

The graphs below depict the emissions performance for each of the modeled Reference Portfolios described above.

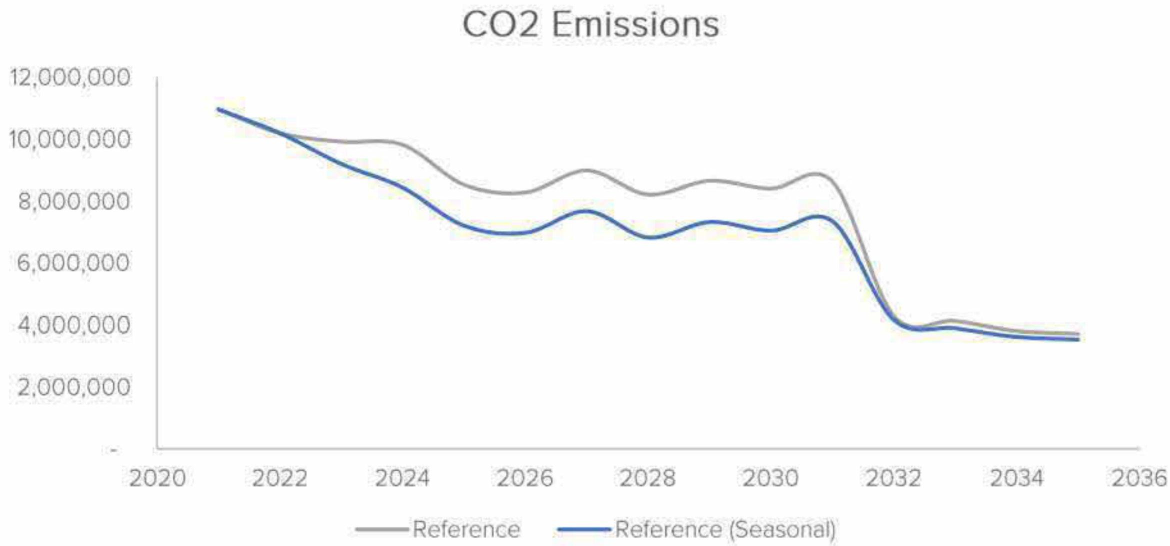

Figure 6: CO2 Emissions in Reference Portfolios with Year-round and Seasonal Operations

3.2 Recommended Optimal Portfolio

Strategen also developed an Optimal Portfolio that minimizes ratepayer costs as determined by the EnCompass model. The Optimal Portfolio includes specific changes to APS's modeling choices around coal and energy efficiency that were not based on economics. Specifically, we relax the Must-Run constraints and allow for economic cycling (i.e., coal units operate only when it is economic to do so), allow generation units to be retired based on economics, and included higher levels of energy efficiency available for the model to select if economic.

The graph below shows the generation mix of the Optimal Portfolio (based on the 0.9% load sensitivity). It includes the economic retirement of Four Corners at the end of 2023, and significant investment in solar, wind, storage, and energy efficiency resources.

	2020-2024	2025-2035	TOTAL (2020-2035)
DEMAND RESPONSE	400	400	800
ENERGY EFFICIENCY	1,712	894	2,606
RENEWABLE ENERGY	1,160	4,100	5,260
ENERGY STORAGE	440	2,780	3,220
MERCHANT PPAS	0	1,028	1,028

Table 5: Incremental Capacity Additions (MW) in the Optimal Portfolio

We then quantified the cost and emissions savings of the Optimal Portfolio against the Reference Portfolio. The Optimal Portfolio resulted in both a lower revenue requirement and lower carbon emissions.

Regarding the emissions performance of the Optimal Portfolio versus the Reference Portfolio, it is important to note the difference in cumulative emissions. Although annual emissions in the 2035 year do not differ significantly, the cumulative emissions in 2021-2035 do differ significantly. This is important since cumulative emissions, rather than annual emissions, (i.e., the stock rather than the flow) is the metric that actually matters with respect to the mitigation of climate change. The cumulative emissions are 50% higher in the Reference Portfolio when compared to the Optimal Portfolio. In addition to the cumulative emissions savings, the Optimal Portfolio results in significant cost savings for ratepayers, reflected in a lower revenue requirement.

In addition to the avoided fuel and O&M, the retirement of the Four Corners units will also result in a reduction of incremental capital expenses. Although this reduction is partially included in the model results by the elimination of the incremental capital expenses beyond 2023, there are additional savings that can be achieved. Specifically, for the years 2021-2023, APS is projecting significant incremental capital expenses at Four Corners. If the unit retired early, these costs could be substantially reduced. This means that in addition to the cost savings, APS could save additional costs by adjusting its incremental capital expenses schedule to reflect an earlier retirement. These savings could also be partially achieved under a seasonal operations scenario if we assume that unit overhauls and other repairs will be happening less frequently due to limited wear and tear of reduced operations.

Finally, the Coal Supply Agreement between APS and the supplier of coal to the Four Corners Power Plant includes a provision that allows the agreement's termination with a 24 month notice if the plant shuts down. The termination of the agreement would also result in a termination fee. This fee reduces the potential cost savings under the Optimal Portfolio, but only to a small degree. According to APS, the Company's share of the termination fee would amount to about $39 million in 2023.[15] Meanwhile, the potential savings from doing so are significantly higher. Aggregating the modeled savings of our recommended Optimal Portfolio against the Reference Portfolio, the reduction in incremental capital expenses, and the payment of APS's share of the termination fee, our recommended Optimal Portfolio results in total ratepayer savings of over $1.4 billion.

[15] DOCKET NO. E-01345A-19-0236, APS response to Sierra Club's Data Request 3.1(d).

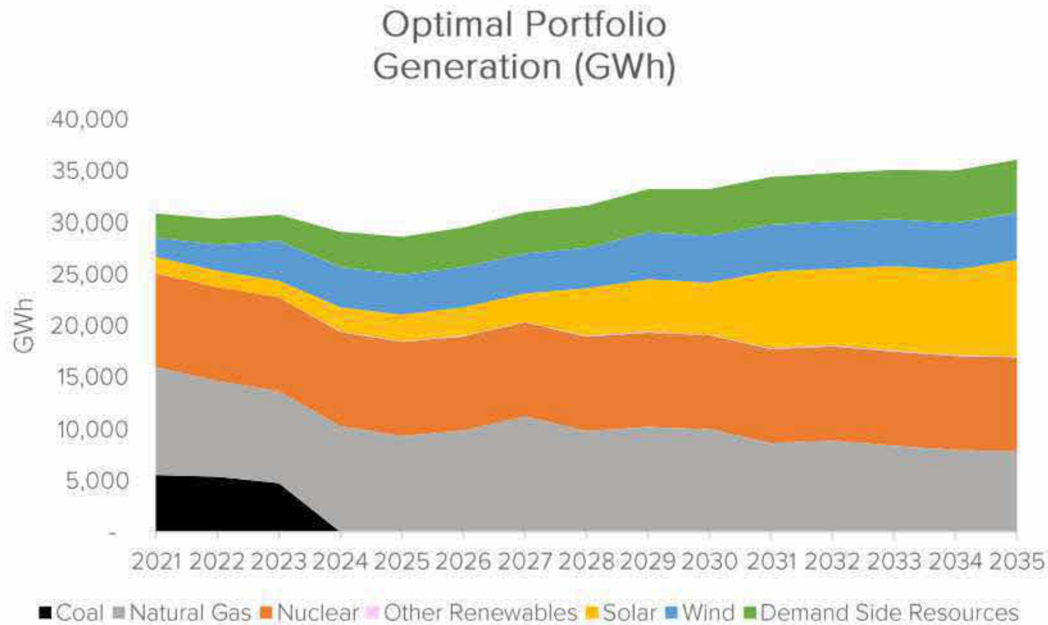

Figure 7: Generation Schedule in Recommended Portfolio

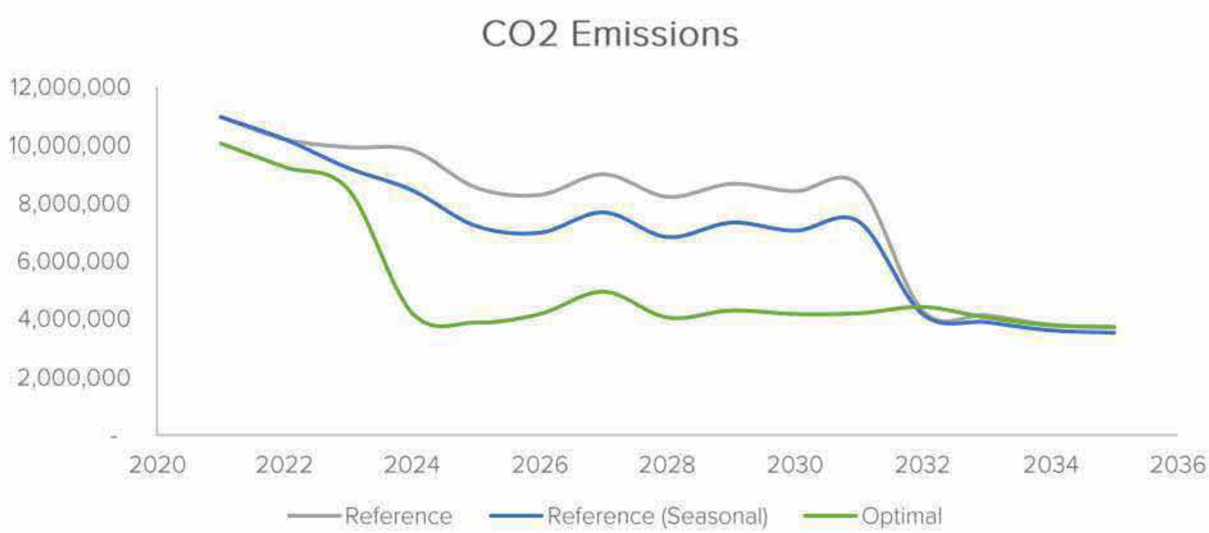

Figure 8: CO2 emissions in the recommended Optimal Portfolio versus Reference Portfolios

Total MW Added	Reference Portfolio (Year-round Must Run)	Reference Portfolio (Seasonal Operations)	Optimal Portfolio
Energy Efficiency	1602	1602	2606
Demand Response	800	800	800
Distributed Energy	1585	1585	1585
Renewable Energy	5300	5440	5260
Energy Storage	4770	4700	3220
Merchant PPA (Natural Gas)	1028	1028	1028
Hydrogen Ready CTs	0	0	0
Revenue Requirement	-$35 million		-$1,388 million
2035 Carbon Emissions	Approximately 4 million tons/year	Approximately 4 million tons/year	Approximately 4 million tons/year
Cumulative Carbon Emissions (2021-2035)	116 million tons	104 million tons	78 million tons

Figure 9: Summary of Model Results. Resources are expressed as incremental MW additions. Revenue Requirement differences between each scenario are based on the Net Present Value for the 2021-2035 period.

3.3 Sensitivities

In addition to the Optimal Portfolio, Strategen conducted several sensitivity analyses that included minor modifications of the Optimal Portfolio. One such sensitivity restricted all investment in fossil fuel resources including the extensions of the merchant gas purchase power agreements (PPAs) in the 2025 timeframe ("No New Gas Sensitivity"). The No New Gas Sensitivity still included the high levels of energy efficiency, additional investment in renewable energy and storage technologies, and the retirement of Four Corners at the end of 2023 as the recommended portfolio of our analysis. The No New Gas Sensitivity also resulted in slightly lower emissions than the initial Optimal Portfolio starting in 2025. The total cost of the portfolio was higher but still significantly lower than the Reference Portfolio.

In addition to the 0.9% load growth assumed in our Reference Portfolio, we also examined the impact of relaxed coal operations and retirement constraints under APS's higher load growth assumption ("high load sensitivity"). The portfolio selected under this High Load Sensitivity was similar to the ones presented above, e.g. significant investment in demand side resources, renewable energy and storage technologies, while at the same time retiring coal unit as early as possible. Understandably, total investment and cost in this scenario is higher than the 0.9% load sensitivity, but still lower than any portfolio including Must-Run and fixed retirement constraints (including our Reference Portfolio).

Finally, we conducted a sensitivity in which we restricted emissions to 90% reductions by 2035 ("90% clean sensitivity"). It is worth noting that in this scenario, the hydrogen ready combustion turbines were indeed included in the final portfolio despite their higher cost due to the level of emissions reduction necessitating additional clean, firm resources on a faster time horizon. The cost of the portfolio, despite being higher than the recommended Optimal Portfolio, was also still lower than the Reference Portfolio. Thus, significant emissions reductions are not only achievable but can come with significant economic benefits for ratepayers under a range of scenarios. However, this depends critically upon economic retirement of coal and the maximization of all economic energy efficiency measures.

4. Conclusion

Our analysis reveals that energy efficiency is one of the most economic resources to be added in the system and recommends that APS increase its investment in it. Furthermore, we find that APS's remaining coal units are highly uneconomic, and their economic retirement earlier than the announced retirement date of 2031 would result in both cost savings and emissions reductions for Arizonans. Finally, we find that there is no need for new investment in thermal resources which would quickly become stranded assets as the utility has committed to 100% clean, carbon free electricity by 2050.

APS's recently announced seasonal operations can reduce carbon emissions and has the potential for cost savings for its ratepayers. However, these savings and emissions could be significantly reduced further by economically retiring the Four Corners units. Our recommended Optimal Portfolio includes higher levels of energy efficiency, renewable energy, and storage technologies, the retirement of Four Corners by the end of 2023, and no new investment in fossil fuel resources and would result in savings of over $1.4 billion for APS ratepayers.

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